Webinar presentation:

The Story of Crossrail: Creation of a Digital Railway

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14 MAY 2020, HONG KONG

UNLOCKING CITIES GLOBALLY

THE STORY OF CROSSRAIL: CREATION OF A DIGITAL RAILWAY

MALCOLM TAYLOR

MARCH 2020

Delivering the UK's megaprojects

"Over the past decade, the UK has transformed the way megaprojects are delivered, moving away from a world of fixed price contracts, risk transfer, lowest-cost tendering and adversarial relationships."

US$5.6bn (£4.3bn)
Heathrow Terminal 5
7 years (2001-2008)

US$11.5bn (£8.77bn)
London 2012 Olympics
7 years (2005-2012)

US$19bn (£14.8bn)
Crossrail, Elizabeth Line
12 years (2009-2021)

US$6.4bn (£4.9bn)
Thames Tideway Tunnel
8 years (2016-2024)

US$115bn (£88bn)
High Speed 2 (HS2)
16 years (2017-2033)

MTRC TRANSFORMATION PROGRAMME

HONG KONG SAR

Crossrail International performed a Quality Management (QM) and benchmarking review against Crossrail's QM system and other best practice industry approaches, working with partners Turner & Townsend. The review of processes and procedures provided the basis for a business-wide transformation programme for MTR Corporation, operator of Hong Kong's Mass Transit Railway.

Core services

- QM framework review
- People, processes and systems transformational change
- Workshops
- Industry best practice benchmarking

Webinar presenter

Malcolm Taylor
BEng MBA CEng MICE MIStructE MHKIE

- Over 40 years of experience in programme and project management, design and construction of major transport infrastructure schemes worldwide

- Leading exponent of the UK's drive for Project Information Management (PIM) and Building Information Management (BIM) maturity in client organisations, using digital technologies

- Served as Head of Technical Information for **Crossrail**, Europe's largest rail infrastructure project, a UK best practice model

- Completed two four-year assignments in Hong Kong with Mouchel (now WSP)

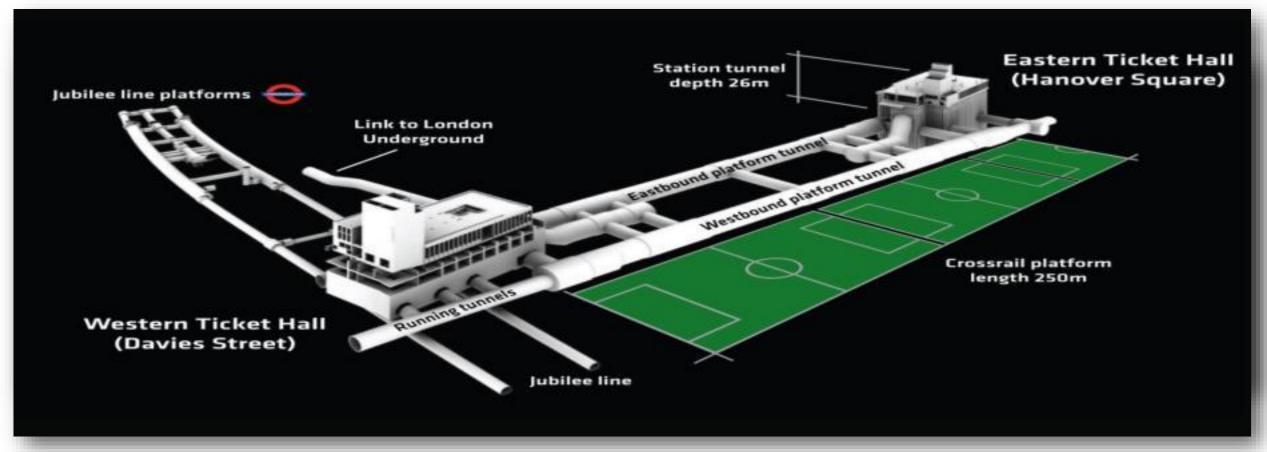# Presentation overview

The Story of Crossrail:

FRONT COVER
Digital rendering of **'Infinite Accumulation'** public art by Japanese artist Yayoi Kusama at Liverpool Street Station, funded by property developer British Land and part of the innovative Crossrail Art Programme.

Chapter 1
Introduction to Crossrail

Introduction to Crossrail - physical

Jubilee line platforms

Link to London Underground

Station tunnel depth 26m

Eastern Ticket Hall (Hanover Square)

Eastbound platform tunnel

Westbound platform tunnel

Crossrail platform length 250m

Running tunnels

Western Ticket Hall (Davies Street)

Jubilee line

42km of tunnel under London

200M Passenger Journeys / annum

200m long trains

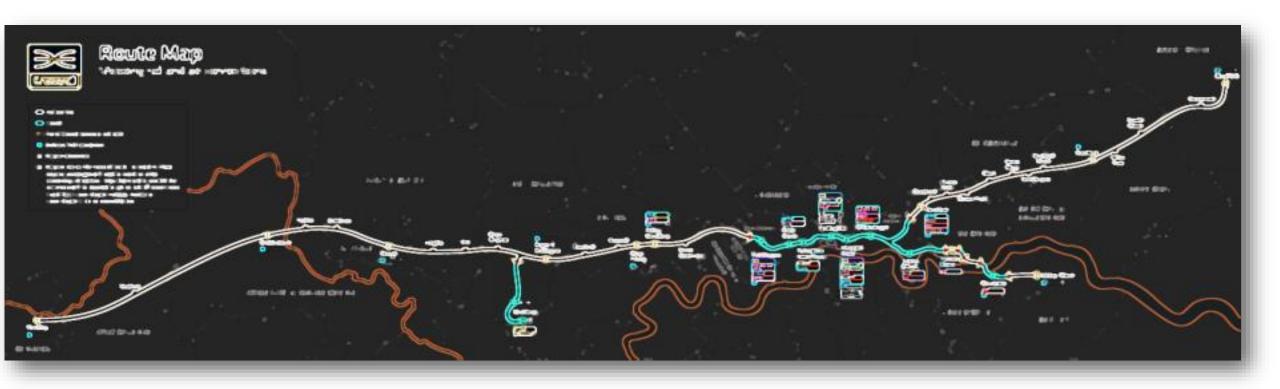**24** Trains per hour in Central Section

10% Increase in Carrying Capacity

Introduction to Crossrail - digital

250k 2D & 3D CAD models

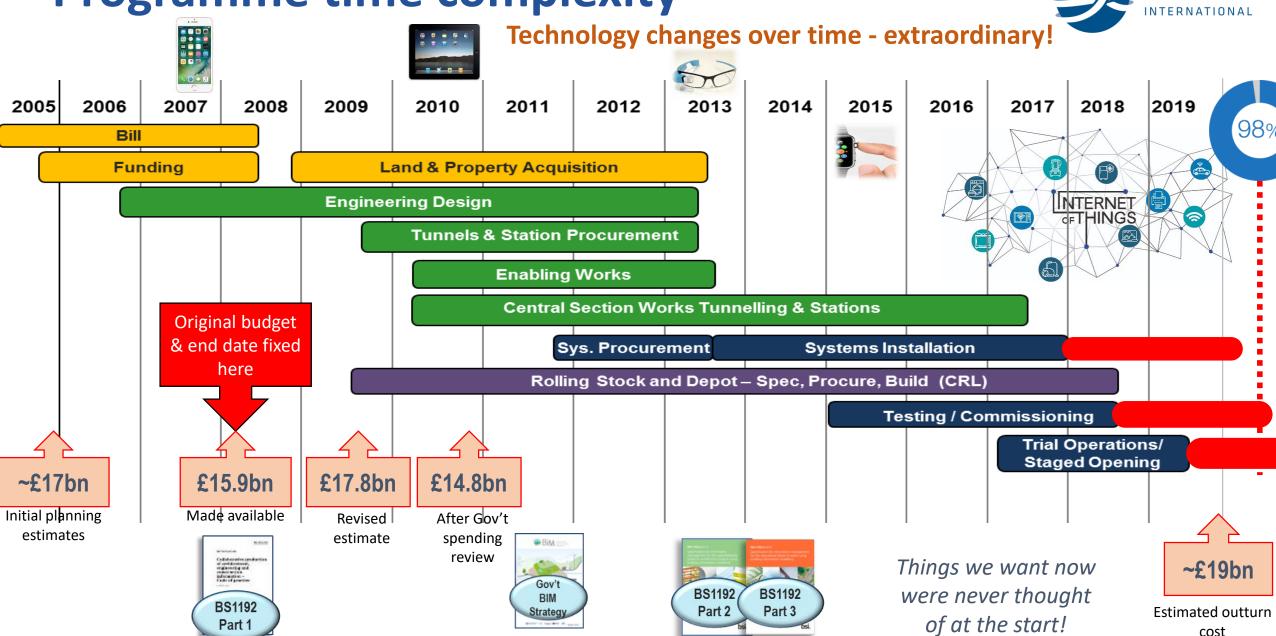**4M** Documents

1M Assets & equipment

500M GIS features

~ £19B Cost

Programme time complexity

Technology changes over time - extraordinary!

Crossrail INTERNATIONAL

| 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |

98%

- Bill
- Funding
- Land & Property Acquisition
- Engineering Design
- Tunnels & Station Procurement
- Enabling Works
- Central Section Works Tunnelling & Stations
- Sys. Procurement — Systems Installation
- Rolling Stock and Depot – Spec, Procure, Build (CRL)
- Testing / Commissioning
- Trial Operations/ Staged Opening

Original budget & end date fixed here

INTERNET OF THINGS

~£17bn
Initial planning estimates

£15.9bn
Made available

£17.8bn
Revised estimate

£14.8bn
After Gov't spending review

~£19bn
Estimated outturn cost

Things we want now were never thought of at the start!

BS1192 Part 1

Gov't BIM Strategy
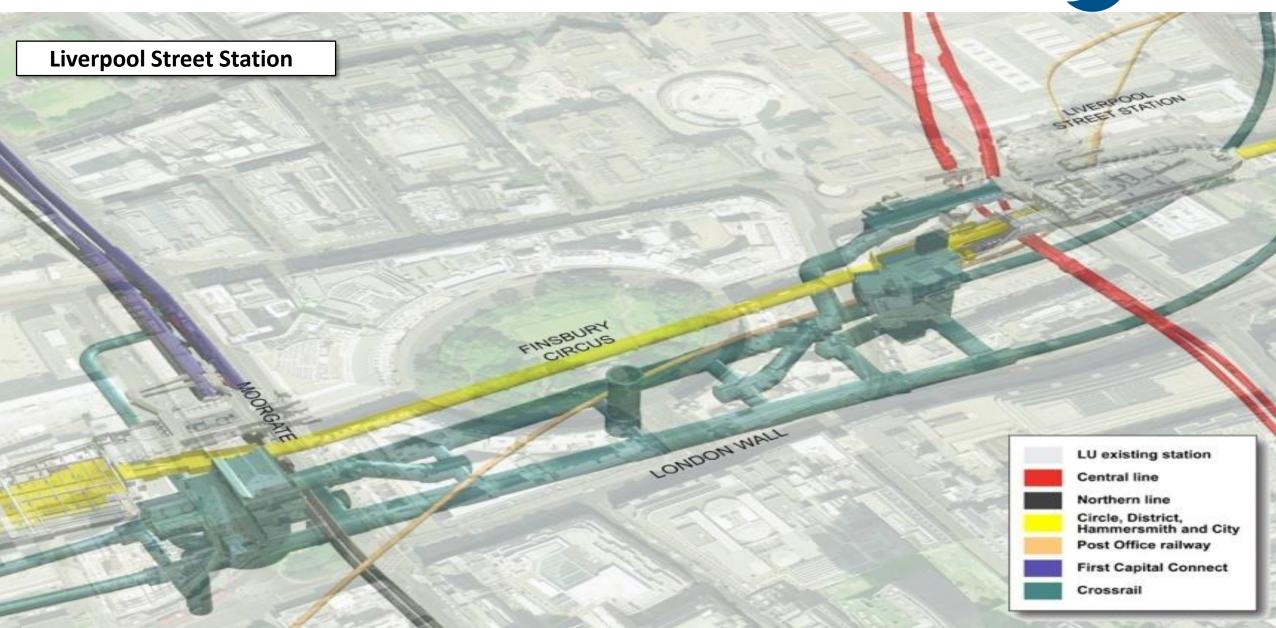
BS1192 Part 2

BS1192 Part 3

Contractual complexity

- **34** Enabling Works Contracts

- **23** Design Contracts

- **45** Delivery Contracts

- **14** other contracts

All use information … and all need to collaborate!
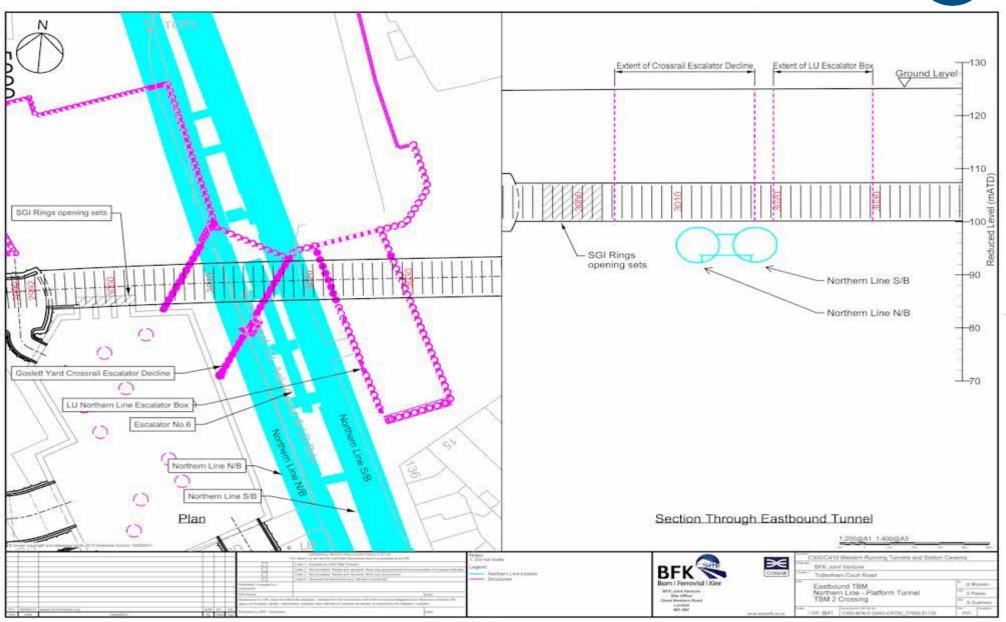
Construction complexity

Liverpool Street Station

Legend:
- LU existing station
- Central line
- Northern line
- Circle, District, Hammersmith and City
- Post Office railway
- First Capital Connect
- Crossrail

Interfacing with others

Chapter 2
Role of the client

Role of the client with respect to BIM and digital
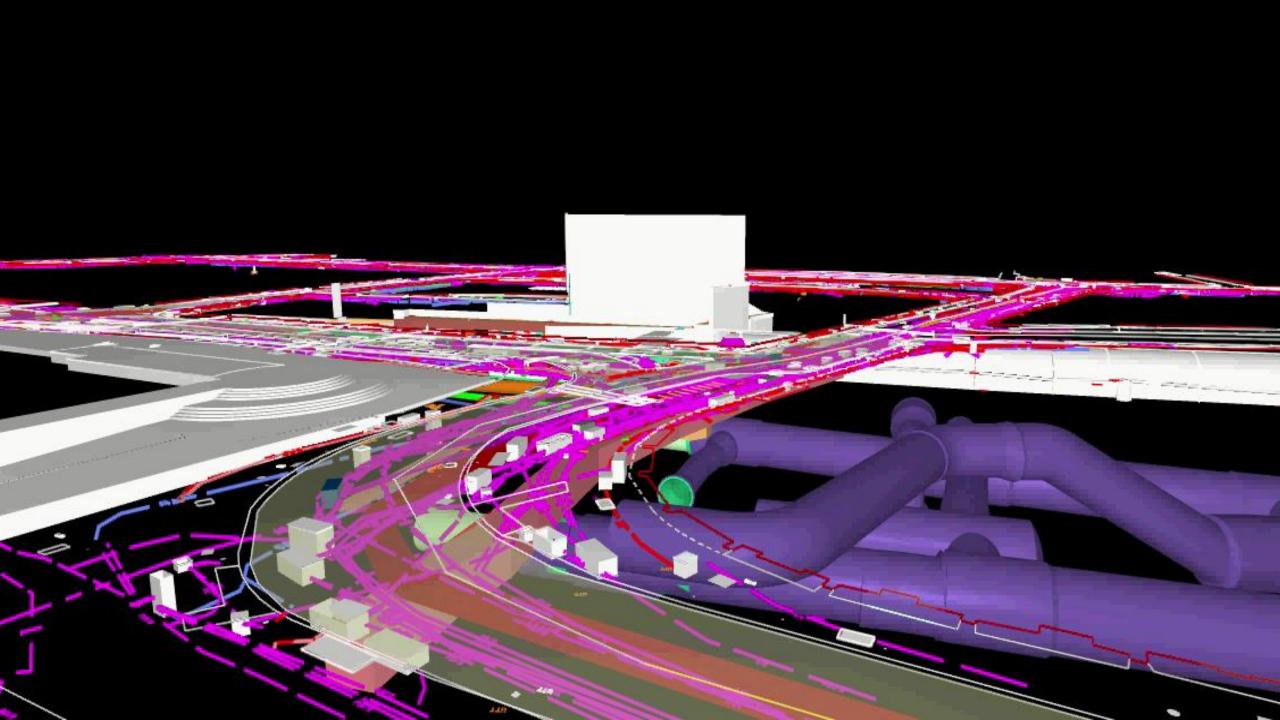
The most critical role

- Owns the building/infrastructure
  - Organises, operates and maintains (£)

- Defines the strategy
  - strategies to achieve business objectives
  - sets requirements and direction
  - procurement principles (often risk-based)

- Creates the BIM and digital environment
  - Collaborative Data Environment (CDE) - or not!
  - Consistent standardised processes - or not!

- Provides leadership to <u>make things happen</u>!

Chapter 3
Crossrail digital basics
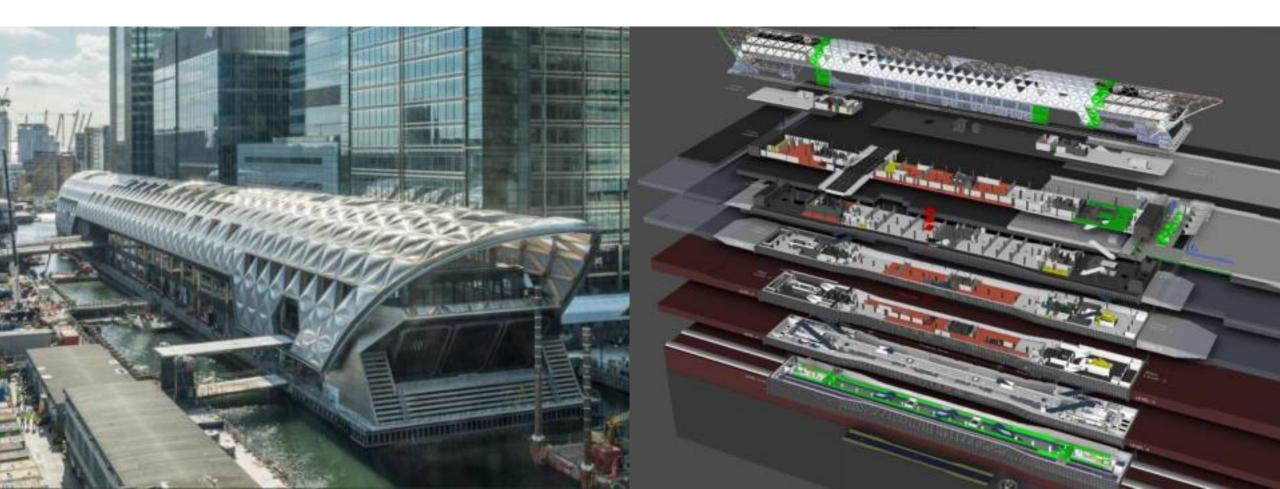
Going digital – building two railways

Physical

Digital
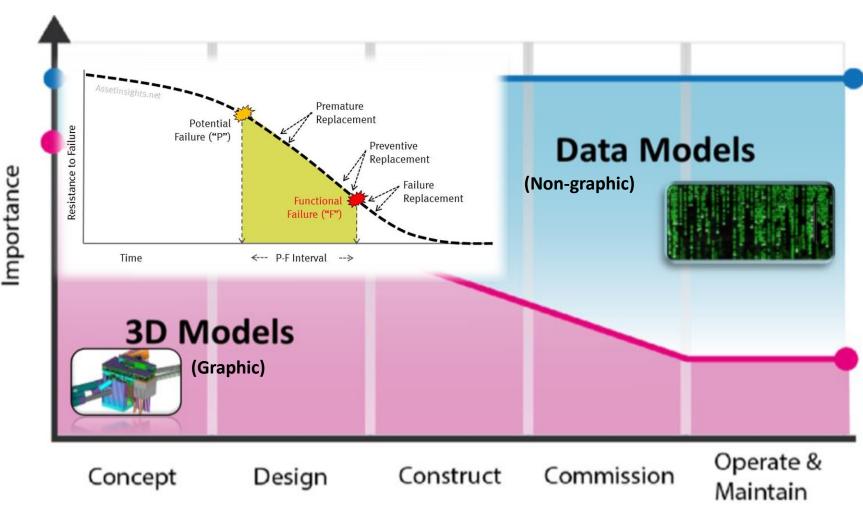
What is BIM? First principles ...

Crossrail
INTERNATIONAL

Why **How** **What**
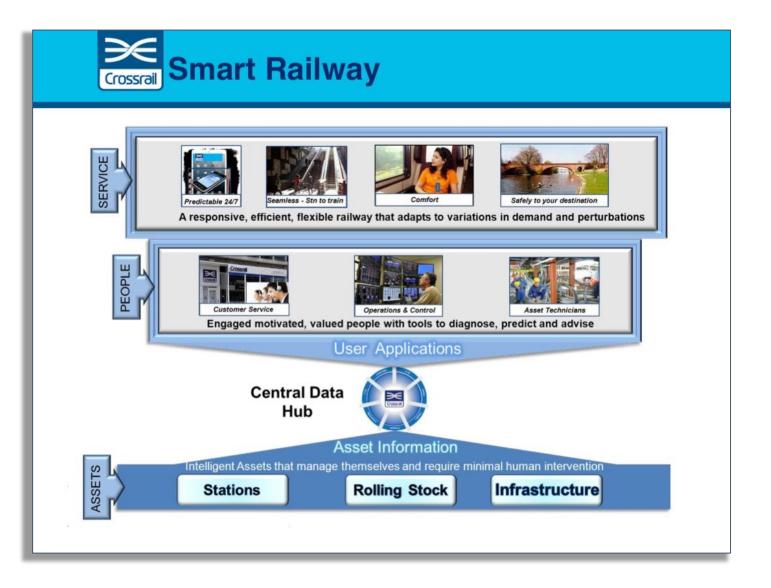
- Information
- Data environment
- Data integrity
- Collaboration
- Technology
- Asset life-cycle
- New processes
- New project culture

Importance

Assetinsights.net

Resistance to Failure

Potential Failure ("P")

Premature Replacement

Preventive Replacement

Failure Replacement

Functional Failure ("F")

Time

←-- P-F Interval -->

Data Models
(Non-graphic)

3D Models
(Graphic)

Concept   Design   Construct   Commission   Operate & Maintain

Understanding what data is needed and when...... to make decisions

2011 Vision for a Smart Railway

Smart Railway

Pre-BIM…..!

- Data centric
- Asset based
- Driven by performance requirements
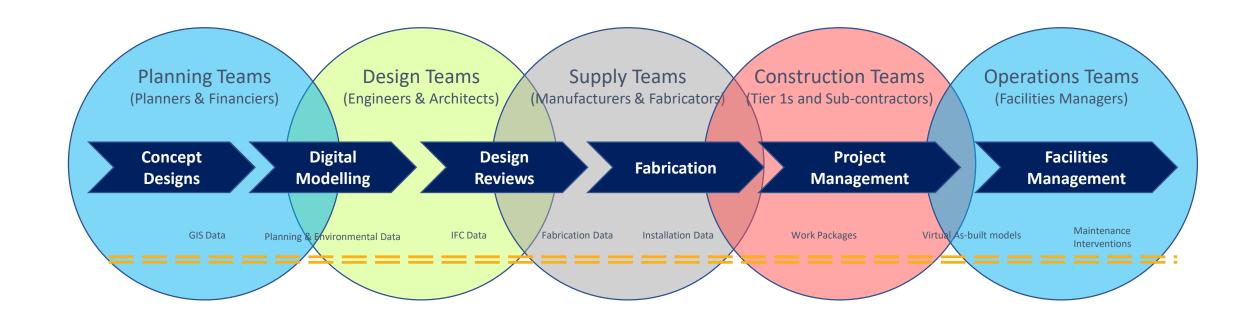
On reflection…
- We didn't try to predict the future
- Limited RCM c.f. Digital Twins today

We recognised the problem of life cycle data

Planning Teams (Planners & Financiers)	Design Teams (Engineers & Architects)	Supply Teams (Manufacturers & Fabricators)	Construction Teams (Tier 1s and Sub-contractors)	Operations Teams (Facilities Managers)
Concept Designs	**Digital Modelling**	**Design Reviews**	**Fabrication**	**Project Management**	**Facilities Management**

GIS Data   Planning & Environmental Data   IFC Data   Fabrication Data   Installation Data   Work Packages   Virtual As-built models   Maintenance Interventions

- Crossrail as client was accountable for all this (even though responsibility was passed to others)
- We needed to ensure **data DNA** remained consistent at, and across, each stage
- *Even more important today for Digital Twins!*

Going digital – key characteristics

Our information and data (BIM) environment

- A defined end-game for all data
  - set out Information requirements
  - created classifications and standard data structures
  - procurement form critical

- A Common Data Environment (CDE)
  - Electronic Data Management System (EDMS) and Enterprise Content Management System (ECMS)
  - used by everyone - contractual
  - owned and managed by the Client

- Leveraging technology
  - databases and master data management

Basic data building blocks

Information sources:

- Client: technical
- Client: delivery
- Client: corporate
- Designers
- Contractors
- 3rd parties
- Utilities
- Developers
- *etc.*

All these needed organising and structuring at the start!

Data and information can be:

- metadata
- structured
- unstructured proprietary

Project data can include:

- Documentation
- Calculations
- Asset inventory data
- CAD data
- Survey/visualisation data
- Sensor data
- *etc.*

Crossrail data structure: case study

Get BIM DNA in place at the start!

Data structure and primary information hierarchies based on:

- Location (LCS plus work sub-locations)
- Contract Codes
- Design Disciplines
- Organisation Codes
- Document Types
- Master Deliverable List, standardised across multiple contracts
- Asset Functions
- Asset Classification (including attribute definition)

An asset breakdown structure:

1. Operating Section *e.g.* Central Section
2. Facility *e.g.* Tottenham Court Road Station
3. Primary Functional Unit *e.g.* Escalator
4. Functional Unit *e.g.* steps
5. Asset *e.g.* step chain

Document/data ID numbering systems:

For all documents, drawings and 3D models:
<Contract>-<Originator>-<Discipline>-<Document Type>-<Asset Location/Sub Location>- <Incremental Number>

e.g. **C330-SKC-O4-TPL-CR076_PT001-00001**

Basis of a Smart Railway: Data (in the CDE)

The link from Assets to business objectives ...
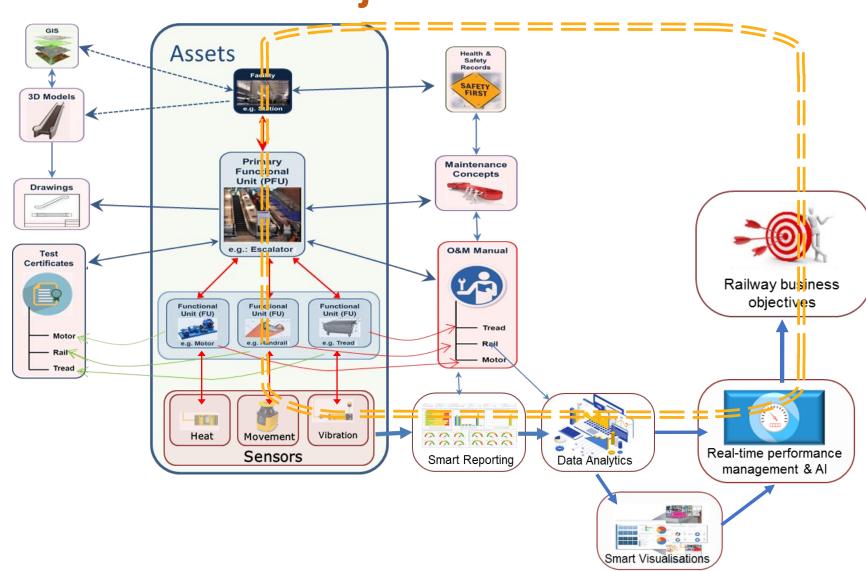
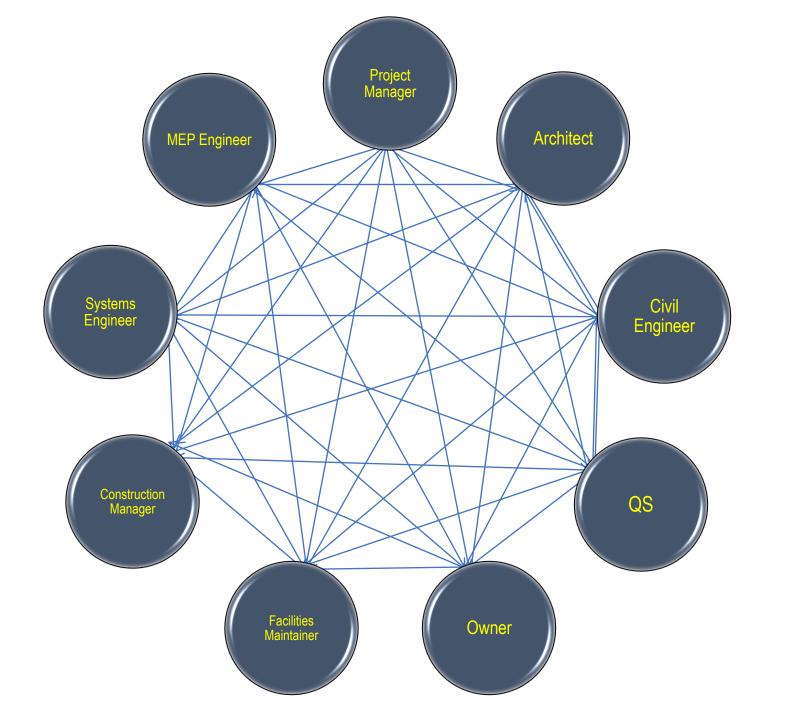**Information relationships defined at the start**
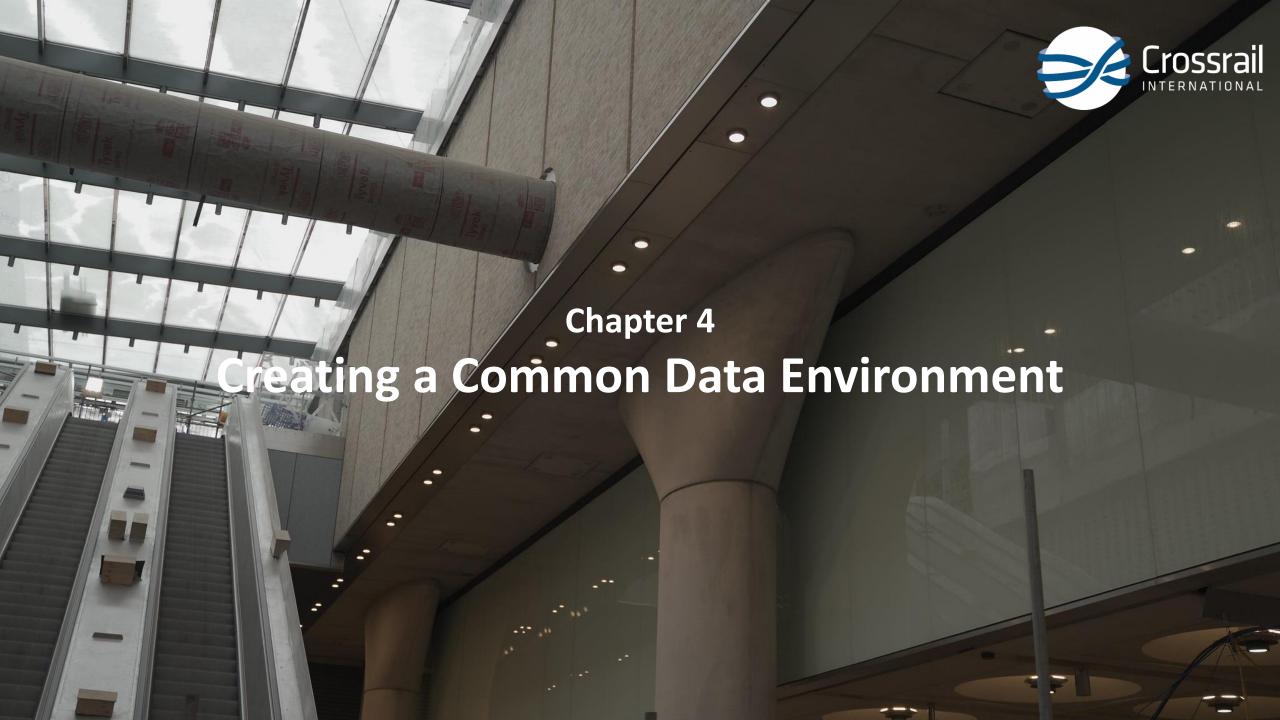
Need to know:
- who wants what
- how data is used in operations
- maintenance interventions
- remote CM

Supply Chain must provide:
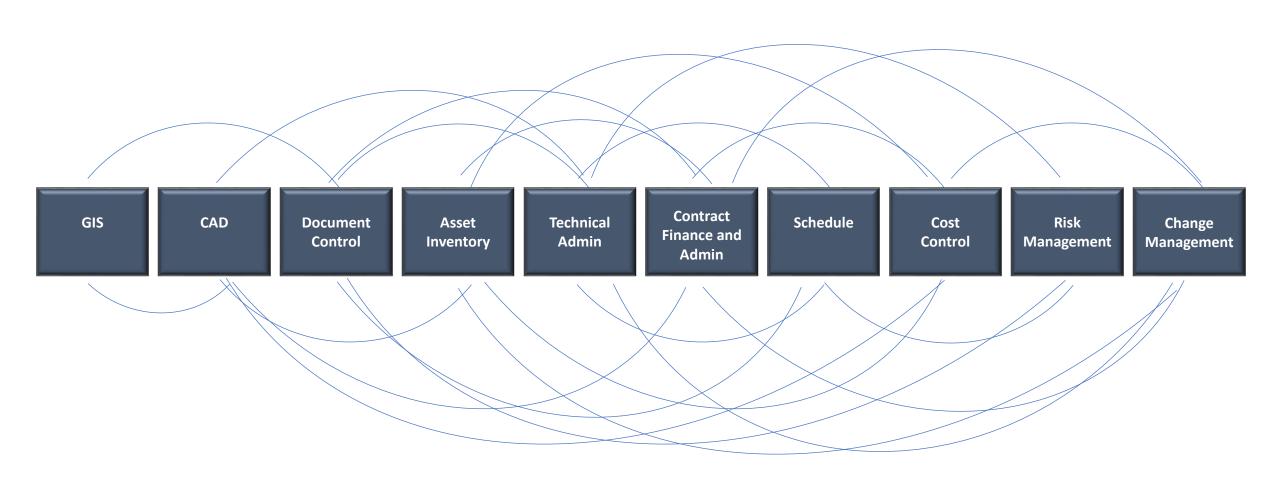- Consistent data
- Accurate data
- Timely data

Chapter 4
Creating a Common Data Environment

A reminder of the old world … when everyone had a hard copy of everything!

Information management in the old world
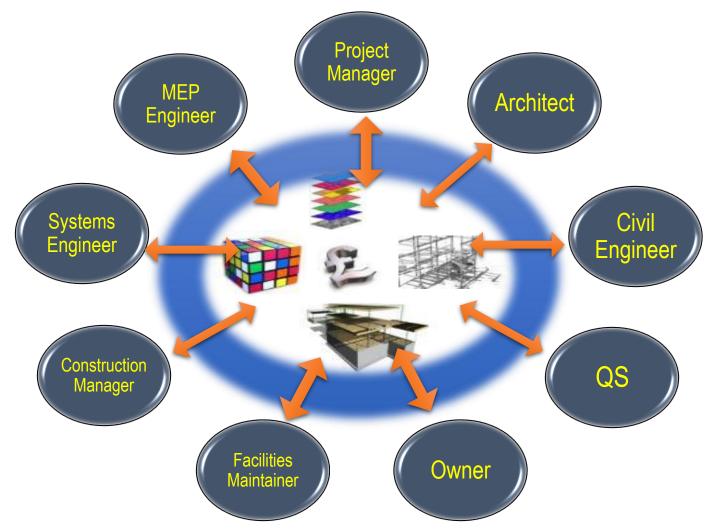
Information management in the new world

We created a Common Data Environment (CDE) embracing new technologies

the process of generating and managing building information during its life cycle …

model-based technology linked with project information databases …

a common data environment:
EDMS (contractual)
CDMS (contractual)
…
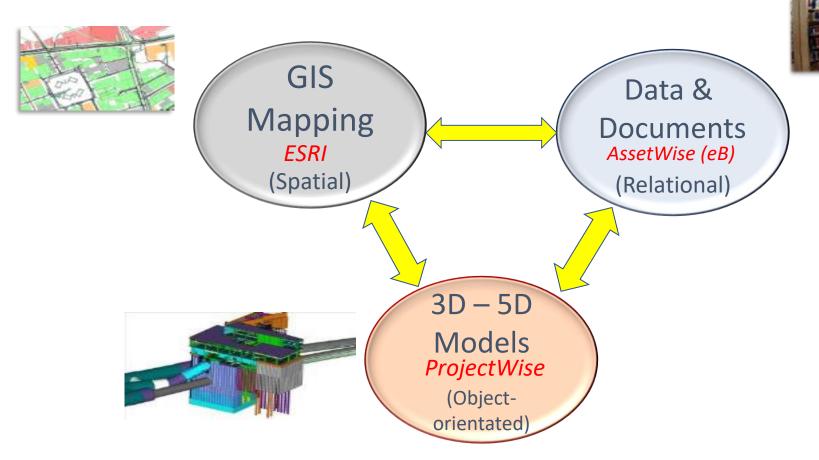
Main CDE

Over 90% of data in three linked databases

GIS Mapping
ESRI
(Spatial)

Data & Documents
AssetWise (eB)
(Relational)

3D – 5D Models
ProjectWise
(Object-orientated)

Main CDE workflows allowed us to get rid of software!

Over 90% of data in three linked databases
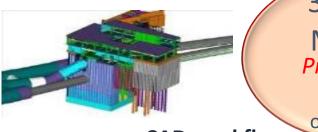
GIS workflows:

- London Survey Grid
- Estates management
- Automated claims reporting
- Integration with CAD

GIS Mapping
ESRI
(Spatial)

Data & Documents
AssetWise (eB)
(Relational)

3D – 5D Models
ProjectWise
(Object-orientated)

CAD workflows:

- CAD user tools
- CAD QC/QA
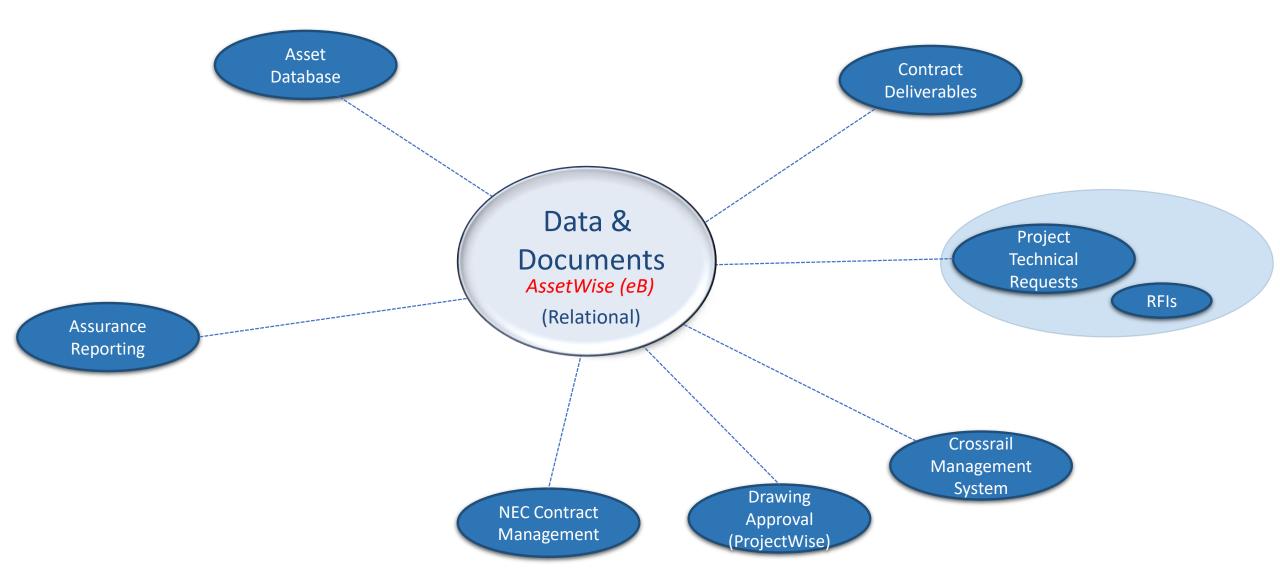- User Management Tools
- Customised BS 1192 Workflow

Documentation workflows:

- NEC3 Contract Management (£8.3bn)
- Asset Inventory Structure (ABS)
- Crossrail Management System (CMS)
- Document Management System
- Assurance reporting
- Materials compliance system
- Project Technical Requests
- Observation reporting
- Snagging
- Automatic pdf drawings from ProjectWise
- Observation reporting
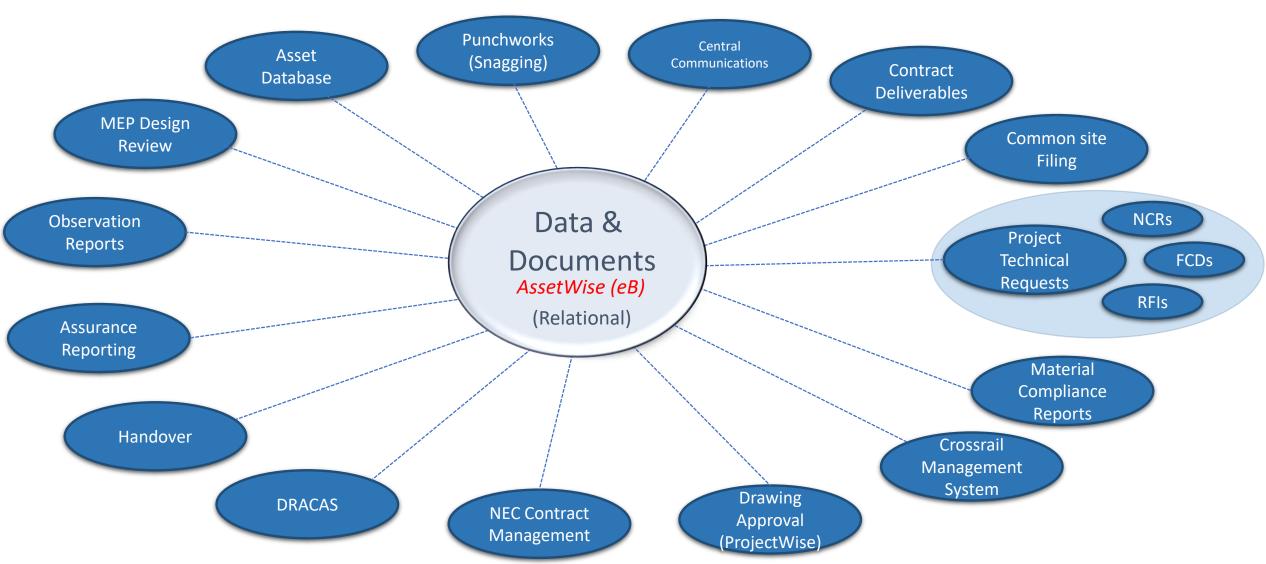- Contract deliverables

Crossrail INTERNATIONAL

Design processes/workflows in CDE

Construction processes/workflows in CDE

Benefits of a CDE

- Better decision-making
- Single source of truth (SSOT)
- Avoids duplication
- Encourages collaboration
- Reduces waste
- Reduces time and cost in producing coordinated data
- Provides consistent reliable data through design, construction and into operations

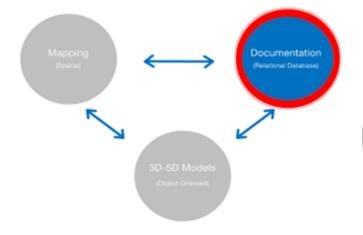**Cost of the documentation/information database:**
Licensing, hosting, *etc.*:	£0.7m per annum
One-off cost of creating workflows, *etc.* in 2010/12	£3.0m

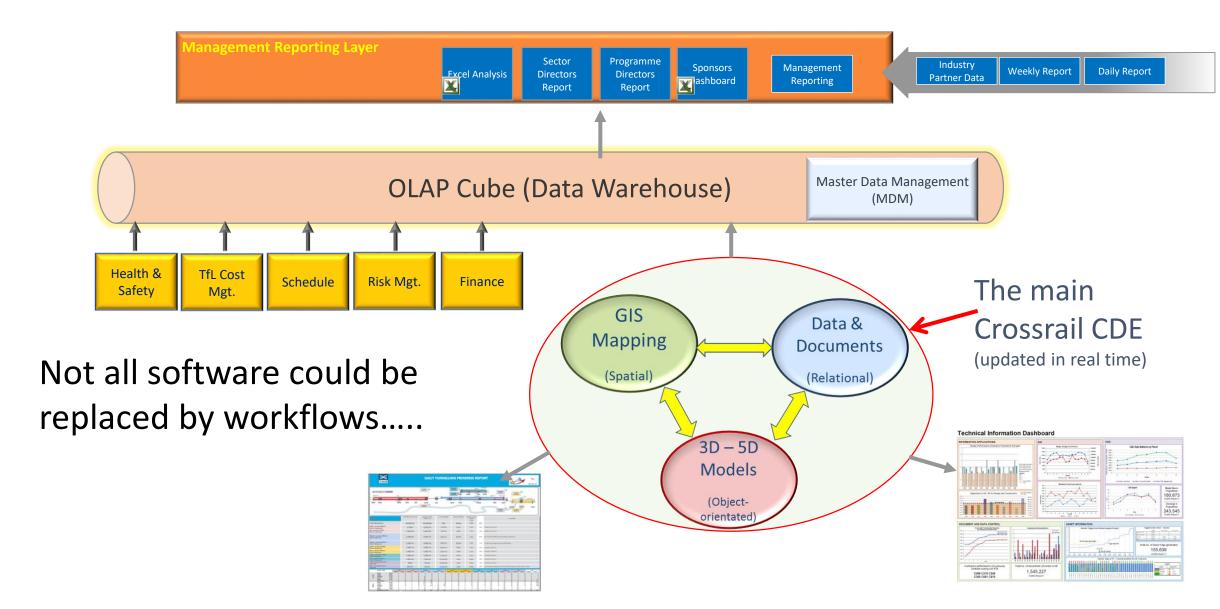**Typical project software costs saved <u>per annum</u>:**
Document control	£1.5m
NEC Contract administration	£2.0m
Project Technical Requests	£2.0m
Asset Inventory Management	£1.0m
Assurance	£1.0m
Snagging	£0.5m
Others	<u>£1.5m</u>

Direct cash benefit ~**£10m** per year for +7 years
plus reduced admin and IT staff **£10m** per year for +5 years
CDE savings – at least 4% of total CAPEX (**£400m**)

Data warehousing for reporting

Crossrail INTERNATIONAL

Management Reporting Layer

Excel Analysis | Sector Directors Report | Programme Directors Report | Sponsors Dashboard | Management Reporting

Industry Partner Data | Weekly Report | Daily Report

OLAP Cube (Data Warehouse)

Master Data Management (MDM)

Health & Safety | TfL Cost Mgt. | Schedule | Risk Mgt. | Finance

GIS Mapping (Spatial)

Data & Documents (Relational)

3D – 5D Models (Object-orientated)

The main Crossrail CDE
(updated in real time)

Not all software could be replaced by workflows…..

Chapter 5
Best practice using data: in design and construction

Defining what's needed and when.....

V-Model assurance life cycle
What you need and when
No EIR, but in contract deliverables

Redefined process and standards

Specifications and Standards

- Developed discipline-based 3D Model level-of-development Specifications and Standards using BS 1192:2007

  - everyone uses our systems

  - we defined how to collaborate

  - defines appropriate levels of detail

  - ensures consistency

- Applies to design and construction
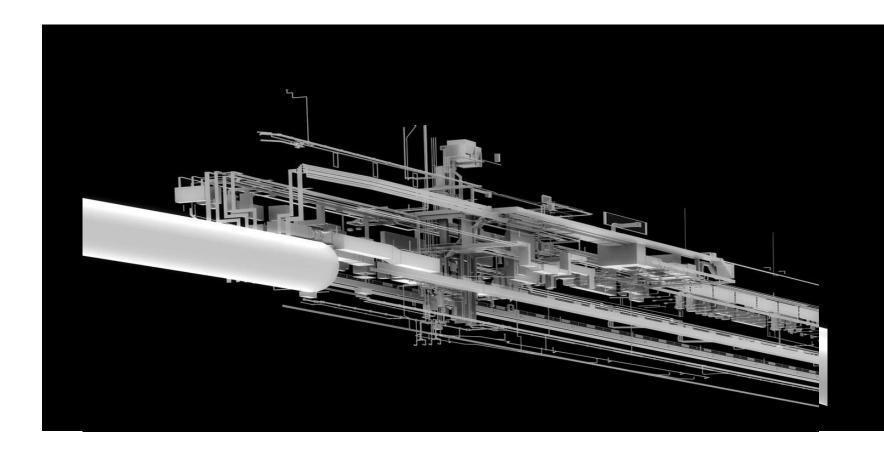
Digital design in 3D

- It's all about space management

- Always required 3D (plus schematics)

- Specific on file format and not software

- Insisted on regular model updates

Digital design in 4D

- Visualisations to improve decision making. Great for:

  - Managing contract interfaces

  - Understanding interdependencies

  - Reducing risks

  - H&S understanding

  - Design accountability issues

  - Site briefings

  - Management awareness

Use of models for 4D and 5D records

Installation Progress Reports

Benefits:

- Efficiencies
  - time savings
  - agreed Earned Value records
  - process improvements
  - Saved up to **£1m per site** where used

- Effectiveness
  - quality record data
  - good assurance data
  - maintenance benefits
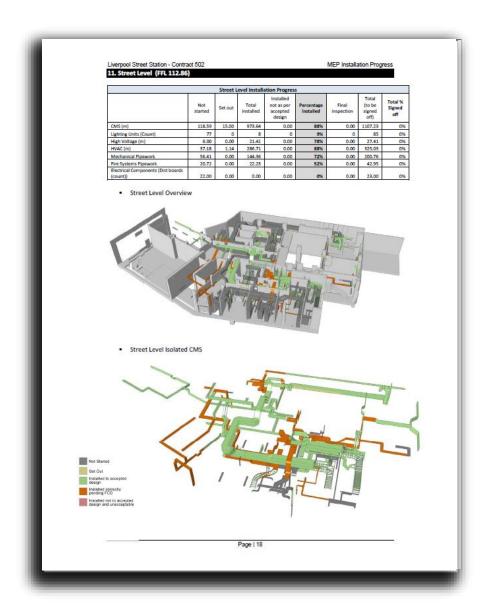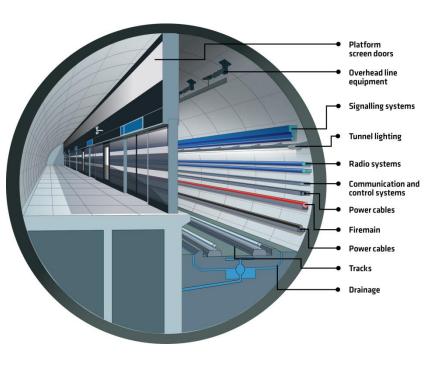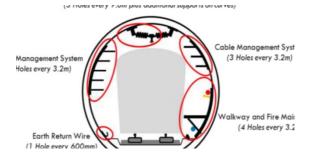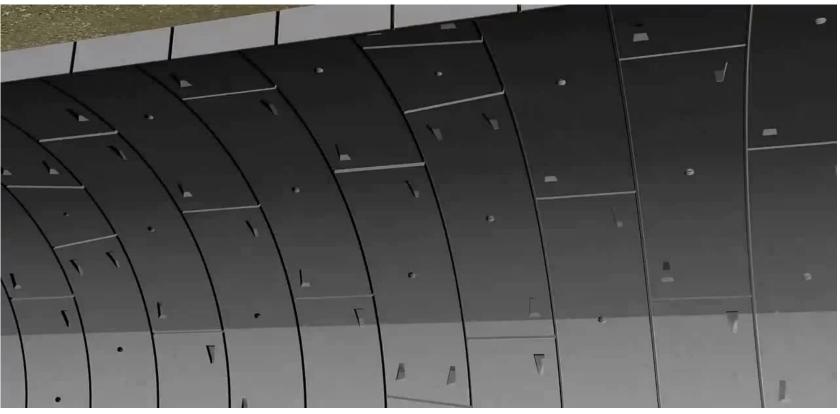
(This took some time to get right!)

Liverpool Street Station - Contract 502 — MEP Installation Progress

11. Street Level (FFL 112.86)

Street Level Installation Progress	Not started	Set out	Total installed	Installed not as per accepted design	Percentage installed	Final inspection	Total (to be signed off)	Total % Signed off
CMS (m)	118.59	15.00	973.64	0.00	88%	0.00	1107.23	0%
Lighting Units (Count)	77	0	8	0	9%	0	85	0%
High Voltage (m)	6.00	0.00	21.41	0.00	78%	0.00	27.41	0%
HVAC (m)	37.18	1.14	286.71	0.00	88%	0.00	325.03	0%
Mechanical Pipework	56.41	0.00	144.36	0.00	72%	0.00	200.76	0%
Fire Systems Pipework	20.72	0.00	22.23	0.00	52%	0.00	42.95	0%
Electrical Components (Dist boards (count))	22.00	0.00	0.00	0.00	0%	0.00	23.00	0%

- Street Level Overview

- Street Level Isolated CMS

Not Started
Set Out
Installed to accepted design
Installed correctly pending FCD
Installed not to accepted design and unacceptable

Page | 18

Use of models in construction

Platform screen doors
Overhead line equipment
Signalling systems
Tunnel lighting
Radio systems
Communication and control systems
Power cables
Firemain
Power cables
Tracks
Drainage

(3 holes every 7.0m plus additional supports on curves)

Cable Management Syst (3 Holes every 3.2m)

Management System Holes every 3.2m

Walkway and Fire Mai (4 Holes every 3.2

Earth Return Wire (1 Hole every 600mm)

Shared models helped offsite manufacturing
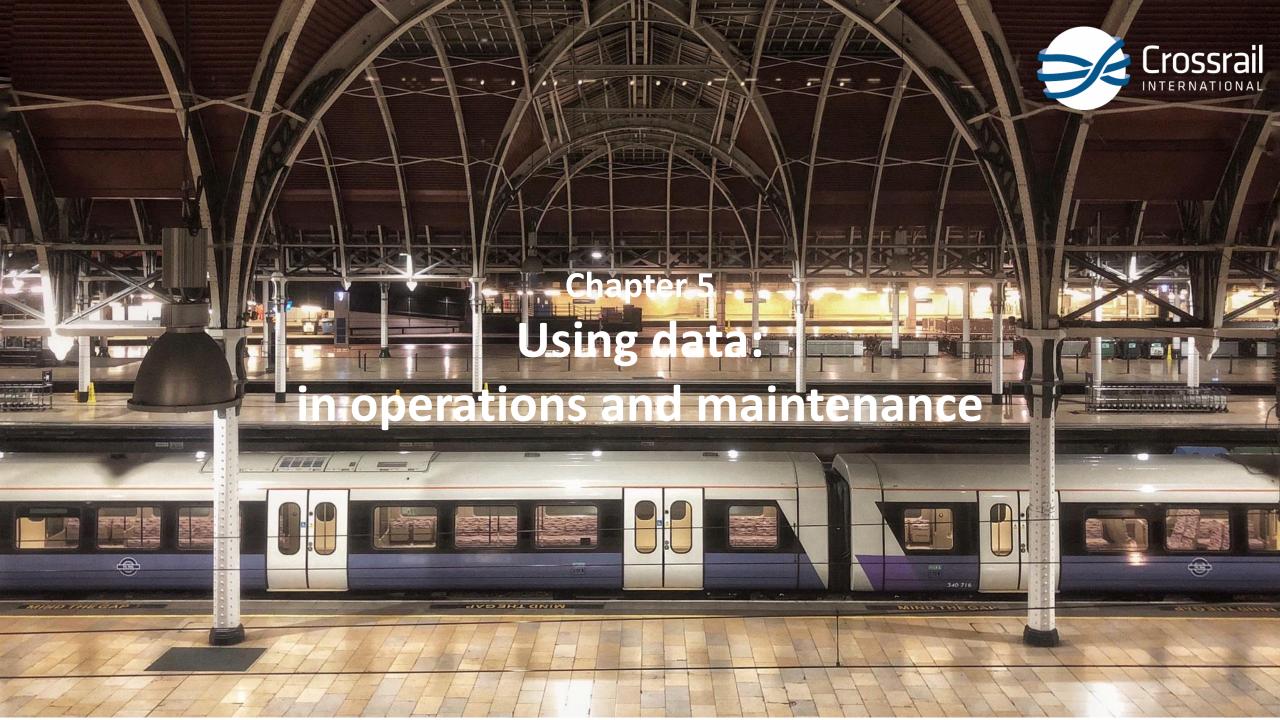
Tottenham Court Road

On site	Off-site	Productivity /hours
57 (c.35% EU labour)	-	67,000hr *At current industry levels*

Liverpool Street
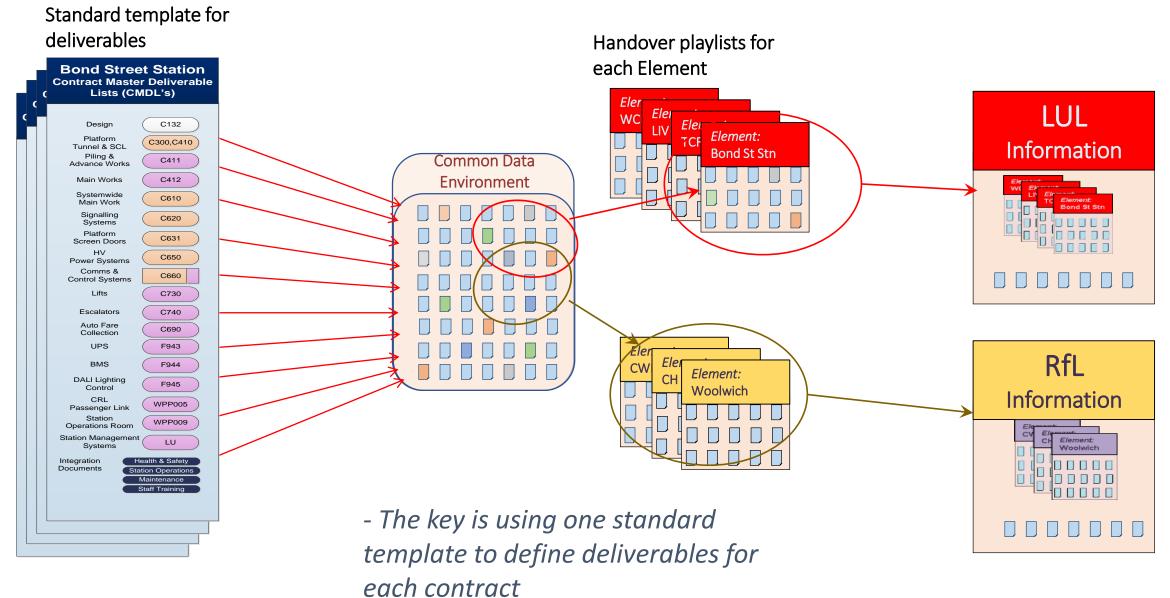
On site	Off-site	Productivity /hours
7	27 (Local labour)	27,000hr *150% increase*
More certain outcomes; regional balance; time, cost and productivity gains		

Chapter 5
Using data:
in operations and maintenance

Digital handover concept

Standard template for deliverables

Handover playlists for each Element

- The key is using one standard template to define deliverables for each contract
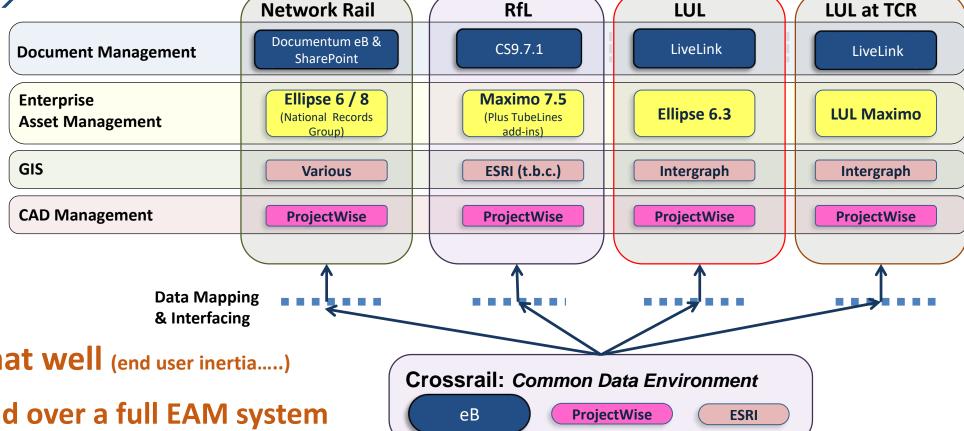
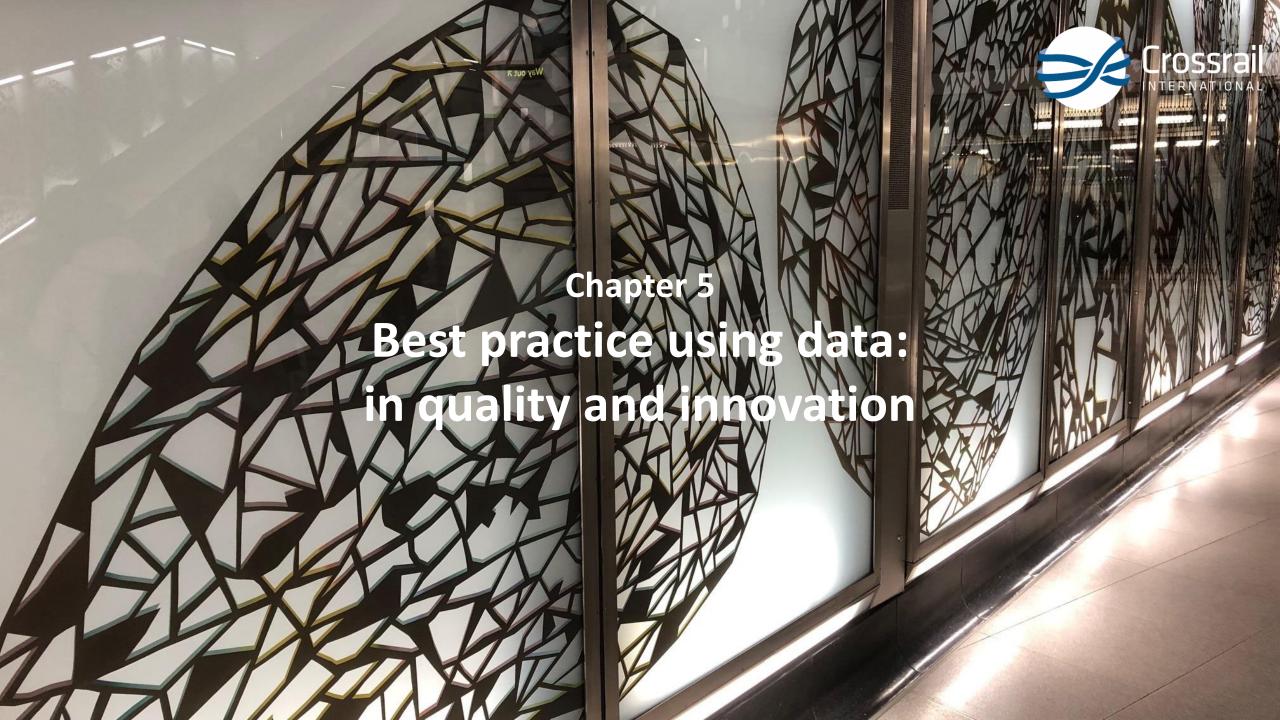# End users need to be digital too!

End users.......→
- Different systems
- Different standards
- Different approaches
- Different people!

Challenge of data alignment & interoperability!

	Network Rail	RfL	LUL	LUL at TCR
Document Management	Documentum eB & SharePoint	CS9.7.1	LiveLink	LiveLink
Enterprise Asset Management	Ellipse 6 / 8 (National Records Group)	Maximo 7.5 (Plus TubeLines add-ins)	Ellipse 6.3	LUL Maximo
GIS	Various	ESRI (t.b.c.)	Intergraph	Intergraph
CAD Management	ProjectWise	ProjectWise	ProjectWise	ProjectWise

Data Mapping & Interfacing

Crossrail: *Common Data Environment*
- eB
- ProjectWise
- ESRI

Not worked that well (end user inertia…..)

Next time – hand over a full EAM system (not just data)

Chapter 5
**Best practice using data:
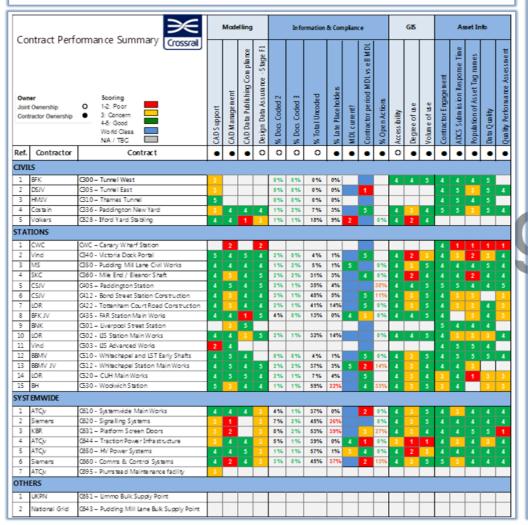in quality and innovation**

Quality control as-you-go (*c.f.* the physical world)

Technical Information Dashboard - Period 8 – 2017/18

The Technical Information Department continued to engage with the contractors and the Crossrail site teams in order to ensure consistently as well as improvements in performance. The summary dashboard illustrates performance and trending in data capture and management.

KEY ISSUES

ASSET INFORMATION

Asset Naming average now 90%.

CAD

Canary Wharf the biggest challenge, ongoing as-built and redline work. Also more detailed discussions with TfL to establish ProjectWise access post-handover.

GIS

Delay in LU workshop to determine handover deliverables leading to further delay in development of RfL GIS platform

INFORMATION & COMPLIANCE

The status of Preliminary Drawings and BS1192 conformance of 'Y' Discipline (non-Projectwise) drawings from Tier 1 contractors is not being accurately reported at Contract Closeout – thereby potentially delaying handover acceptance.

Coordination is required with Central Delivery and CAD compliance.

KEY STATISTICS

Total no. of documents in eB
2,890,073 (57%)
+1.26% Period 8

Model files in ProjectWise
308,236 (61%)
+0.7% Period 8

Drawings in ProjectWise
373,754 (74%)
+0.84% Period 8

Corporate Information - Directorate Plans Completed
8 / 11
+1 Period 8

Contractor with >4% Docs Coded 2
4 / 20
-1 Contract Period 7

Total no. of Asset Tags Estimated
553,261
+2.38% Period 8

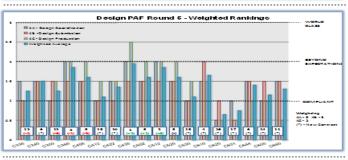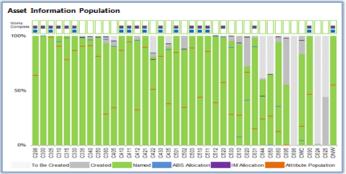Total no. of Asset Tags Created
541,061 (98%)
+1.06% Period 8

Total no. of Asset Tags Named
503,094 (91%)
+0.22% Period 8

Exploiting innovation
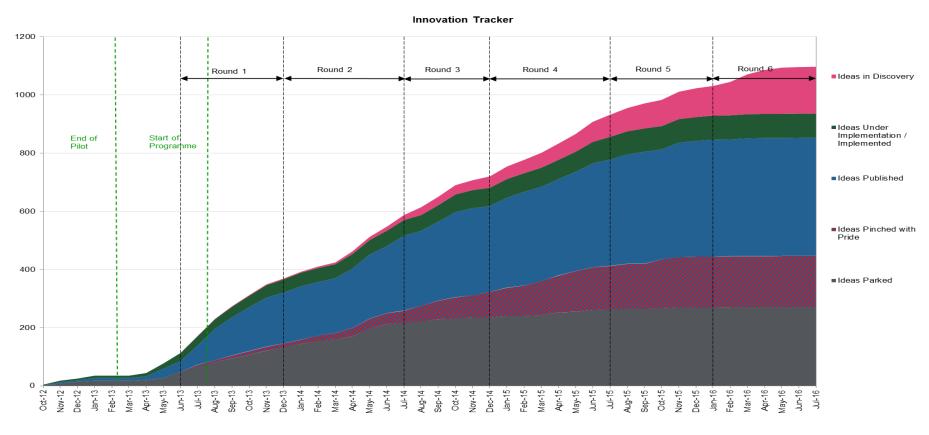
- Initially 10 Tier 1 contractors → 18
- £25k per contractor
- CRL £ 250k
- Sharing ideas (30% BIM or digital)

INNOVATE 8

i3P INNOVATING THE FUTURE
helping transform ideas into opportunities

Innovation Tracker

- Very successful: RoI = 3.8
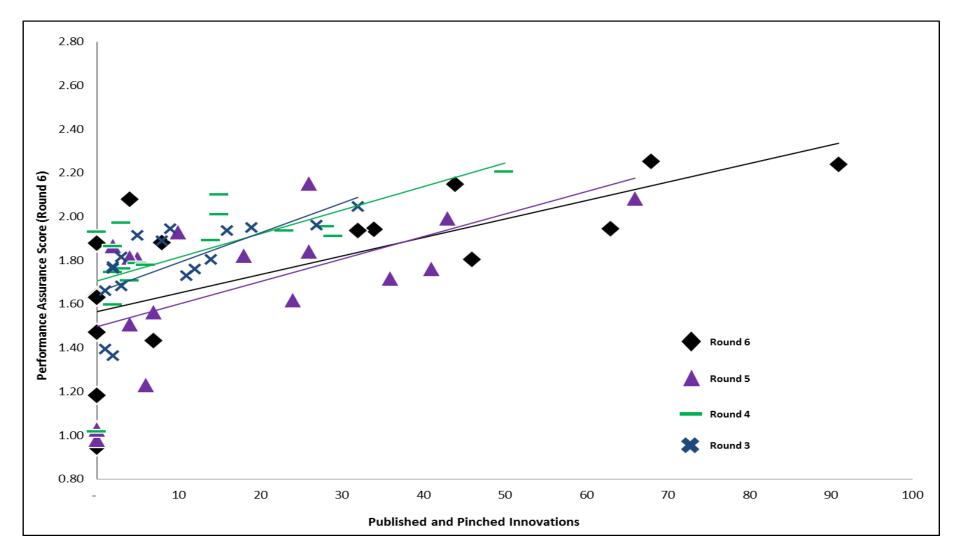- Became UK-wide as i3P

- Showcase for invested projects: £700k+ invested in over 60 projects
- Knowledge library: 450+ innovations published online

Contractor performance and innovation

The best innovators, especially in digital and BIM, were the best performers

Note:
Form of contract is key

... and finally ...

ELIZABETH LINE

Crossrail
INTERNATIONAL

345 025

XR343

Crossrail in numbers from the CDE today

~£19,000,000,000	Cost
3,610,261	e-Documents stored – so far!
1,047,529	Work Orders issued – so far!
470,580	Assets being defined – so far!
387,147	Drawings – so far!
22,710	Individual CDE users – so far!
2602	Organisations
60	Main Construction contracts
23	Main Design contracts
3	Future maintainers
1	**CROSSRAIL**

Going digital has made it possible!

Learning legacy

12 Learning Legacy Themes

- Project and Programme Management
- Procurement
- Authorisations and Consents
- Land and Property
- Health and Safety
- Environment
- Engineering
- Operations
- Talent and Resources
- External Affairs
- Innovation
- Information Management and Technology

http://learninglegacy.crossrail.co.uk/

Epilogue
Where is digital twin technology taking us?

Digital Twins....

- As a digital replica of something in the physical world, a **digital twin** provides insights into improving operations, increasing efficiencies and identifying key issues ... before they happen in the real world!

Digital Twins improve Asset Knowledge

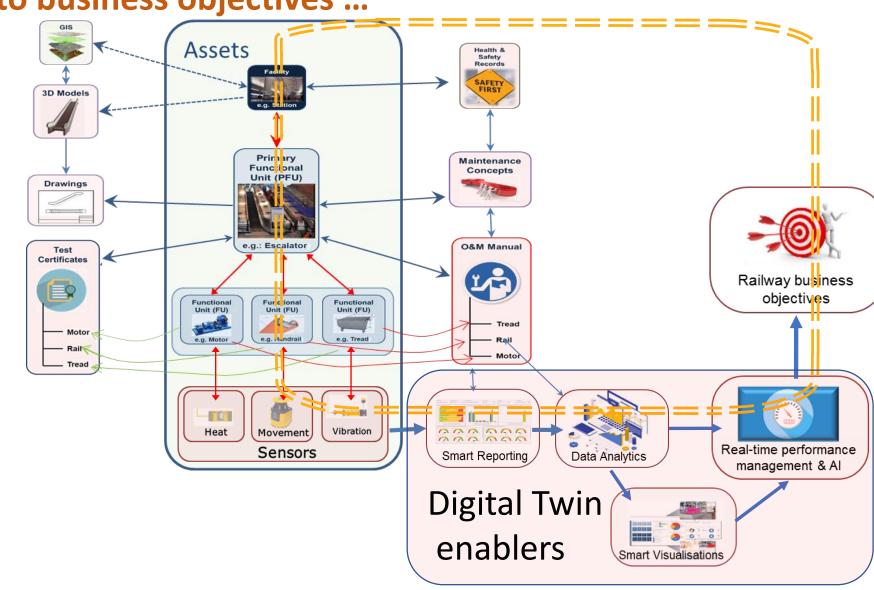## The link from Assets to business objectives …

Information relationships defined at the start

Supply Chain must still provide:
- Consistent data
- Accurate data
- Timely data

Digital Twins
- Use latest technologies
- Use best data practices
- Need contractual definition
- Issues of understanding benefits and how to exploit

Our challenges for the future!

Digital Twin enablers

Summary from the Crossrail story

All projects should be digital!

- Consistent, reliable data (and it's DNA)

- Unified and standardised processes

- 'Single source of truth' (CDE) to manage information and data

- Digital twins for data analytics, AI and smart performance

- Time efficiencies

- Optimised processes

- Improved quality and effectiveness

= better decision making

Outcomes:

- Reduced life cycle delivery and operational costs

- Reduced client, investor and developer risks in updating the future

- Makes assets easier to manage and more attractive to let, sell or retain

BUT, you need a DIGITAL STRATEGY to make this happen!

THANK YOU

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UNLOCKING CITIES GLOBALLY

Q&A DISCUSSION